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ABSTRACT

This study explored the mental components that are most important for successful problem solving. Four components were studied: cognition, metacognition, noncognitive variables, and justification skills. It was hypothesized that cognition and knowledge of cognition would predict success at solving well-structured problems, which have one correct answer and typically only one way to reach a final solution. It was further hypothesized that regulation of cognition, justification skills, and noncognitive variables, in addition to cognition and knowledge of cognition, would predict success at solving ill-structured problems, which have no correct answers and multiple ways to reach a final solution. The first study included 118 ninth graders from a Midwestern high school and the second study included 1,160 middle school students. Results of the two studies support the hypothesis that mental components used in problem solving depend on the nature of problem solving tasks. Different problem solving tasks require different mental components. To promote students' problem solving skills, educators must develop teaching and learning strategies that use different cognitive components. More research, using appropriate instruments, should explore the role of justification skills in solving problems. (Contains 2 tables and 25 references.) (SLD)

Essential Components for Solving Various Problems in Multimedia Learning Environments

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INTRODUCTION

The purpose of this study was to explore which mental components are most important for successful problem solving. Researchers have argued that problem solving is a complex skill that is influenced by a set of mental components namely, cognition, metacognition, non-cognitive variables and justification skills (Jonassen, 1997; Sinnotte, 1989; Voss, 1988). The extent to which these related components contribute towards successful problem solving depends on the nature of the task (Brabeck & Wood, 1990). Using regression analysis we sought to determine which mental components are necessary for various problem-solving tasks.

For this study we investigated four mental components: cognition, metacognition, non-cognitive variables, and justification skills. Cognition helps learners find an appropriate solution from memory (Glaser, 1989). Metacognition helps learners understand and regulate their performance during problem solving. Knowledge of cognition is one part of metacognition. It is necessary when solvers do not have appropriate solutions in memory. With knowledge of cognition, students can search for general strategies that may be used to solve the problem. Regulation of cognition such as monitoring, evaluating, and planning is another part of metacognition. It is required when learners need to solve problems that have no clear solutions and require large amounts of information in various content areas (Kluwe & Friedricksen, 1985; Rainer & Gunnar, 1985). Non-cognitive variables (e.g., affect, value, motivation, emotionality, and attitude) keep learners going and motivate them to continue through the process (Jonassen, 1997; Sinnott, 1989). Finally, justification skills are necessary when learners have to solve problems that have commonly divergent or alternative solutions (Voss, 1988; Voss & Post, 1989). They allow students to develop a rationale for the solution and defend it against alternatives.

We hypothesized that cognition and knowledge of cognition would predict success at solving well-structured problems, which have one correct answer and typically only one way to reach a final solution (Simon, 1978 & 1979; Bransford & Stein, 1984; Newell & Simon, 1972). On the other hand, we hypothesized that regulation of cognition, justification skills, and non-cognitive variables, in addition to cognition and knowledge of cognition, would predict success at solving ill-structured problems, which have no correct answers and multiple ways to reach a final solution (Voss, 1988; Sinnotte, 1989).

METHOD

Participants/Procedure

Study 1 included 9th grade students (n = 118) from a Midwestern high school. Students used the high school version of *Astronomy Village®*, which focuses on stars and

stellar evolution. They conducted one investigation over a four-week period. The measures of problem solving and mental components related to this study were administered as posttest only.

Study 2 included 6^{th}-8^{th} grade students (n = 1160) from a variety of middle schools throughout the United States. These students used the middle-school version of *Astronomy Village*, which focuses on solar system content. Students conducted anywhere from 2-4 investigations over a four-week period. The measures of problem solving and mental components related to this study were administered both pre and post. (For a more detailed description of the two *Astronomy Village* programs refer to Pompea & Blurton, 1995; McGee & Howard, 1999).

Measures of Problem-Solving (Dependent Measures).

Study 1 used an open-ended response format to present students with both well-structured and ill-structured problems. There were two well-structured problems. One asked students to describe how they would find the distance to a nearby star. The other asked how they would use variable stars to determine the distance to a nearby galaxy. These problems were developed based on the content covered in *Astronomy Village* and required students to explain the approach they took to reach a final solution. Both well-structured problems have a correct answer.

There were also two ill-structured problems. One asked students to describe how they would form a team to investigate whether or not an asteroid is on a collision course with Earth. This one was considered less-structured since it was an extension of ideas presented in *Astronomy Village.* The second asked students to select the site for a new telescope from a list of three alternatives, none of which is optimal. Since this problem was not related to the content in *Astronomy Village* it was considered ill-structured. Both ill-structured problems allow for multiple possible answers. These open-ended response items have been validated in a previous study (Hong, 1998).

Study 2 used a multiple-choice format to measure problem solving skills. We decided to use a multiple-choice format for middle-school students, rather than an open-ended response format, because we felt that the writing ability at that age level would not allow for accurate assessment of problem solving. There were 26 multiple choice items that focused on students' ability to draw conclusions from data and to infer planetary processes from planetary images. For example, students may be presented with a variety of data about an imaginary planet's surface features and asked to determine whether it would be fruitful to search for life on that planet. The validation of this assessment instrument is in progress and will be reported in the final paper.

Measures of Mental Components (Independent Measures).

In Study 1, students' cognition was measured by asking students to classify important concepts related to a given problem. In addition, they had to describe the relationships between the selected concepts (Clark, 1990; Jonassen, Beisser, & Yacci, 1993). Metacognition was measured using the How Do You Solve Problems (HSP) inventory (see Fortunato, Hecht, Tittle, & Alvarex 1991). HSP is a 21-item likert scale inventory that measures those aspects of metacognition in which the subject calls upon knowledge of cognition and regulation of cognition. Justification skills were measured by open-ended essay questions that asked students to justify their final solutions. In Study 2,

cognition was measured using multiple choice questions. The validation of this instrument is in progress and will be reported in the final paper. Metacognition was measured using the Inventory of Metacognitive Self-Regulation (IMSR) developed at the Center for Educational Technologies™. See Howard, McGee, Hong, & Shia (2000) for the validation of this instrument. It measures both knowledge of cognition and regulation of cognition. Study 2 did not have a measure of justification skills. Both Study 1 and Study 2 used the Test of Science Related Attitudes as a measure of non-cognitive skills, values, attitudes, and beliefs toward science (Fraser, 1978;Smist, Archambault, & Owen, 1994).

RESULTS

Simultaneous regression analytic techniques were used to test which components among all those entered in the analysis were statistically significant predictors of different degrees of structured problem-solving scores. The overall results from the regression analysis can be summarized by the following chart.

Variables Kinds of Problems	R^2	Cognition	Justification Skills	Knowledge of Cognition	Regulation of Cognition	Non-Cognitive Variables
MC Well-Structured	57%**	β =.73**	N/A	β =.09**		
OE Well-Structured	47%**	β =.38**	β =.43**			
OE Less-Structured	61%**	β =.28*	β =.46**			β =.15*
OE Ill-Structured	48%**	β =.48**	β =.32**		β =.20*	

Note. MC: Multiple Choices. OE: Open-ended. ** = $p < .000$. * = $p < .01$.
β indicates a significant predictor.

The results of the present study support the hypothesis that mental components used in problem solving depend on the nature of the problem solving tasks. Overall, cognition was a powerful predictor for all degrees of structured problem-solving scores. The results support the theory that students who possess an appropriate, well-organized knowledge base are able to solve problems directly because they recognize each problem from previous experience and know which moves are appropriate (Chi, et al., 1981; Glaser, 1984; Resnick, 1983). It was hypothesized that justification skills would be an important component for solving ill-structured problems but not well-structured problems. However, it turned out to be an important predictor for all open-ended problem-solving scores. The results indicate that if students can provide logical arguments to support their opinion in a given situation, they may successfully solve an open-ended problem whether it is well- or ill-structured (Voss, 1988; Voss & Post, 1989; Jonassen, 1997).

Knowledge of cognition is a strong predictor of multiple choice, well-structured problem-solving scores. It supports the theory that students require the use of general searching strategies when they do not posses previous experience with a specific type of problem (Chi, Bassok, Lewis, Reimann, & Glaser, 1988; Gick, 1986). However, the results did not show that knowledge of cognition is a predictor in open-ended problem solving. It indirectly showed that knowledge of cognition may not be sufficient for finding a solution for open-ended problems. Alternatively, regulation of cognition was a strong predictor in solving only open-ended ill-structured problems. It is consistent with the theory that students need to use regulation of cognition to keep track of the solution

activity and the effects of their efforts because of the uncertain ill-structured problem situation (Kluwe & Friedrichsen, 1985; Herbert & Diome, 1993; Rebok, 1989). The results suggest that problems have to be complicated enough to challenge students to use regulation of cognition for reaching successful solution. In other words, students may not need to use regulation of cognition if the problems lack conceptual and structural complexity, even though they have those skills.

Non-cognitive variables were indicated as an important component for solving an open-ended, less-structured problem but not an ill-structured problem (Sinnott, 1989; Sheurman, 1995). A potential reason for the non-significance in the case of the ill-structured problem may be due to the nature of the problem task. In the ill-structured problem students had to consider multiple perspectives such as budget, human life, and geography, which were not directly related to science, in order to reach a successful solution. Although students may not have a strong positive attitude, value, and belief toward science, they may be encouraged to continue solving the problem by an internal affective reward from the other issues in the problem.

CONCULSIONS

The results of this study have important implications for instructional practice, especially for science education in a multimedia learning environment. The overall results of the investigation illustrate that different problem solving tasks require different mental components. Therefore, in order to promote students' problem-solving skills, educators must develop teaching and learning strategies that use different cognitive components. Specific educational goals and the problems adapted for their instruction must in turn be designed to build specific cognitive skills.

The investigation also suggests additional issues that seem particularly fruitful for future exploration. One set of issues centers around the role of justification skills in problem solving. This study used students' written responses and did not use them in the second study for measuring justification skills because of the lack of available instruments for young students. More research, using appropriate instruments, should explore the role of justification skills in solving problems. Finally, future studies should explore whether the results found in this study generalize to other kinds of problem domains. Additional studies of different disciplines should examine whether the results are consistent with those of this study.

REFERENCES

Brabeck, M. M. & Wood, P. K. (1990). Cross-sectional and longitudinal evidence for difference between well-structured and ill-structured problem solving abilities. In M. L. Commons, C. Armon, L. Kohlberg, F. A. Richards, T. A. Grotzer, and J. D. Sinnott (Eds.), Adult development 2: Models and methods in the study of adolescent and adult thought (pp. 133-146) New York: Praeger.

Bransford, J. D., & Stein, B. S. (1983). The IDEAL problem solver: A guide for improving thinking, learning, and creativity. New York: W. H. Freeman.

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. Cognitive Science, 5, 121-152.

Chi, M. T. H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. Advances in the psychology of human intelligence (pp. 7-77). Hillsdale, NJ: Lawrence Erlbaum.

Clark, H. T. (1990). Recall of information separating two inconsistent propositions: An experimental test of the cognitive dumping hypothesis. Paper presented at the annual meeting of the Eastern Educational Research Association, Clearwater, FL.

Fortunato, I., Hecht, D., Tittle, C. K., & Alvarez, L. (1991). Metacognition and problem solving. Arithmetic Teacher, 7, 38-40.
Fraser, B. L. (1978). Development of a test of science-related attitudes. Science Education, 62, 509-515.
Gick, M. L. (1986). Problem-solving strategies. Educational Psychologist, 21(1&2), 99-120.
Glaser, R. (1989). Expertise and learning: How do we think about instructional processes information processing: The impact of Herbert A. Simon. Hilsdale, NJ: Lawrence Erlbaum.
Herbert, M. E., & Dionne, J. P. (1993). Implicit theories about everyday problem solving. Paper presented at the Annual Meeting of the American Educational Research Association, Atlanta, GA. (ERIC Document Reproduction Service No. ED 359 246).
Hong, N. (1998). The relationship between well-structured and ill-structured problem solving in multimedia simulation. Unpublished doctoral dissertation. The Pennsylvania State University, University Park. [Online] Available:www.cet.edu/research/papers.html.
Howard, B. C., McGee, S., Shia, R., & Hong, N. S. (2000, April). Metacognitive self-regulation and problem-solving: Expanding the theory base through factor analysis. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA. [Online] Available:www.cet.edu/research/papers.html.
Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. Educational Technology: Research and Development, 45(1), 65-94
Jonassen, D. H., Beissner, K., & Yacci, M. (1993). Structural knowledge. Hillsdale, NJ: Lawrence Erlbaum.
Kluwe, R. H., & Friedricksen, G. (1985). Mechanisms of control and regulation in problem solving. In J. Kuhl, & J. Beckmann (Eds.), Action control: From cognition to behavior (pp. 183-218). New York: Springer-Verlag.
McGee, S. & Howard, B. (1999, April). Generalizing activity structures from high school to middle school science. In S. McGee (Chair), *Changing the game: Activity structures for science education reform.* Symposium submitted to the annual meeting of the American Educational Research Association, Montreal, Canada. [Online] Available:www.cet.edu/research/papers.html.
Newell, A., & Simon, H. (1972). Human problem solving. Englewood Cliffs, NJ: Prentice Hall.
Pompea, S. M., & Blurton, C. (1995, Jan-Feb). A walk through the Astronomy Village. Mercury, p. 32-33.
Resnick, L. B. (1983). Mathematics and science learning: A new conception. Science, 220(4596), 477-98.
Rebok, G. W. (1989). Plans, actions, and transactions in solving everyday problems. In J. D. Sinnott (Ed.), Everyday problem solving: Theory and applications (pp. 100-122). New York: Praeger.
Simon, D. P. (1978). Information processing theory of human problem solving. In W. K. Estes (Ed.), Handbook of learning and cognitive process. Hillsdale, NJ: Lawrence Erlbaum.
Sinnott, J. D. (1989). A model for solution of ill-structured problems: Implications for everyday and abstract problem solving. In J. D. Sinnott (Ed.), Everyday problem solving: Theory and applications (pp. 72-99). New York: Praeger.
Smist, J. M., Archambault, F. X., & Owen, S. V. (1997). Gender and ethnic differences in attitude toward science and science self-efficacy among high school students. Paper presented at the American Educational Research Association Annual Meeting, San Francisco.
Voss, J. F. (1988). Problem solving and reasoning in ill-structured domains. In C. Antaki (Ed.), Analyzing everyday explanation: A casebook of methods (pp. 74-93). London: SAGE Publications.
Voss, J. F., & Post, T. A. (1988). On the solving of ill-structured problems. In M. T. H. Chi, R. Glaser, & M. J. Farr (Eds.) The nature of expertise. Hillsdale, NJ: Lawrence Erlbaum.

Table 1. Intercorrelations among the Independent Variables in Problem Solving Analysis

Variable	1	2	3	4	5
	Students (n = 118 (1200))				
1. Content Understanding	---				
2. Justification Skills	$.67^3$	---			
3. Non-Cognition	$.44^3$ (.02)	$.34^3$	---		
4. Knowledge of Cognition	$.27^2$ ($.20^3$)	.20*	$.54^3$ ($.17^3$)	---	
5. Regulation of Cognition	$.19^1$ ($.13^3$)	.13	$.37^3$ ($.16^3$)	$.69^3$ ($.69^3$)	---

Note. $^1 p < .05$. $^2 p < .01$. $^3 p < .001$. ( ) numbers are the results from the Study 2.

Table 2. Summary of Simultaneous Regression Analysis for Variables Predicting Different Degrees of Structured Problem-Solving Scores

Variables	B	SE B	β	T	P
Multiple Choice Well-Structured Problem-Solving Scores (N = 1200)					
Content Understanding	1.22	.03	.73	35.79	.000
Knowledge of Cognition	1.00	.22	.09	4.45	.000
Constant	2.90	.81		3.59	.004
R^2 = .57 (p < .000)					
Open-Ended Well-Structured Problem-Solving Scores (N = 118)					
Content Understanding	.62	.12	.38	5.04	.000
Justification Skills	.34	.06	.43	5.64	.000
Constant	1.44	.69		2.1	.038
R^2 = .47 (p < .000)					
Near-Transfer Ill-Structured Problem-Solving Scores (N = 112)					
Content Understanding	.90	.37	.28	2.43	.017
Justification Skills	1.11	.28	.46	3.88	.000
Science Attitude	.022	.009	.15	2.42	.017
Constant	- 2.75	2.02		- 1.36	.176
R^2 = .61 (p < .000)					
Far-Transfer Ill-Structured Problem-Solving Scores (N = 111)					
Content Understanding	2.72	.41	.48	6.57	.000
Justification Skills	.49	.12	.32	4.30	.000
Regulation of Cognition	.26	.10	.20	2.70	.008
Constant	4.05	1.87		2.17	.032
R^2 = .48 (p < .000)					

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